Comparison of a sectional and a modal cloud microphysics representations for Venus: VenLA vs. MAD-VenLA

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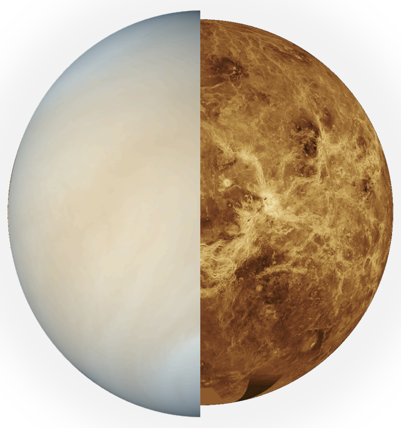
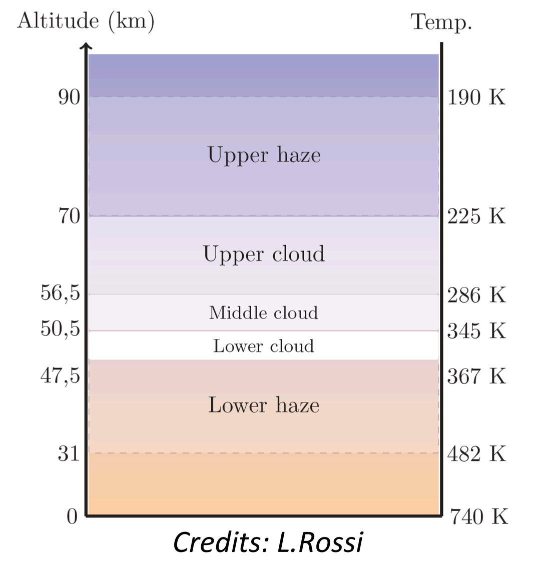
CONTEXT



Credits: ESA

Venus is a terrestrial planet **enshrouded by clouds**. The thickness of these clouds is more or less **20 km**. We can distinguish three layers: top, middle and lower cloud decks. The cloud particles are mainly composed of sulphuric acid (H_2SO_4) and few water (H_2O) [4,10]. The droplet radii distribution can be separate into three modes: mode 1 (r_{mean} ± 0.2 µm), mode 2 (r_{mean} ± 1.0 µm) and mode 3 (r_{mean} ± 3.5 µm) [3]. The Venus clouds play a crucial role in radiative transfer and the climate of the planet.

To study the atmosphere and the climate, the LMD and the LATMOS are developing a **3D IPSL Venus-GCM** (Global Climate Model, [6]). Our goal here is to develop **a microphysical model to complete this IPSL Venus GCM**.



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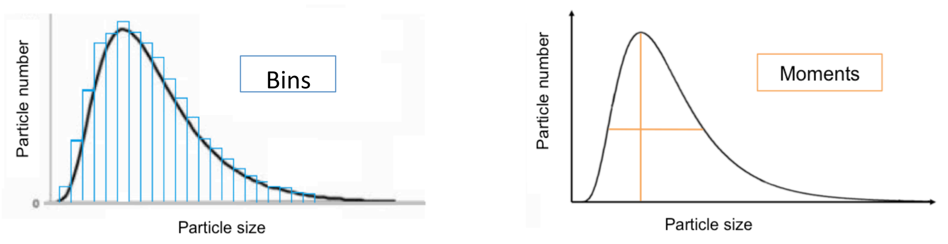
MODELLING METHOD

To understand the formation of clouds, we need to follow the evolution of cloud droplets. Two distribution representations are used here.

SECTIONAL REPRESENTATION

The **Venus Liquid Aerosol** (VenLA) cloud model is a sectional model [7]. This method consists to represent the distribution in several radii intervals, called **bins**. At high radius resolution, the bin representation is **computationally too intensive** to be integrated in the 3D IPSL Venus-GCM because each bin is a tracer in the Global Climate Model. Often in GCMs another representation is used: the moment method.



MODAL REPRESENTATION

The **Modal Aerosol Dynamics of Venusian Liquid Aerosol** cloud model (MAD-VenLA) uses moment scheme to describe the size distribution function and the microphysical processes.

The droplet radii distribution is described by **global parameters** [9]. In theory, this method is **computationally more efficient** than a sectional representation [1].

Here, We develop MAD-VenLA.

MAD-VenLA PRESENTATION

- Model in **0 D** (without transport).
- The droplets are liquid and composed of H_2SO_4 and H_2O.
- The **shape** of the distribution function **is fixed** and is a log-normal function.
- Moments associated with meaningful parameters.
  The standard deviation is **fixed**.
  We take two moments :
  - **M_0** relative to the total number of particles ;
  - **M_3** relative to the total volume of the droplet distribution.
- We take into account mode 1 and 2, but we present here only the results on mode 1.

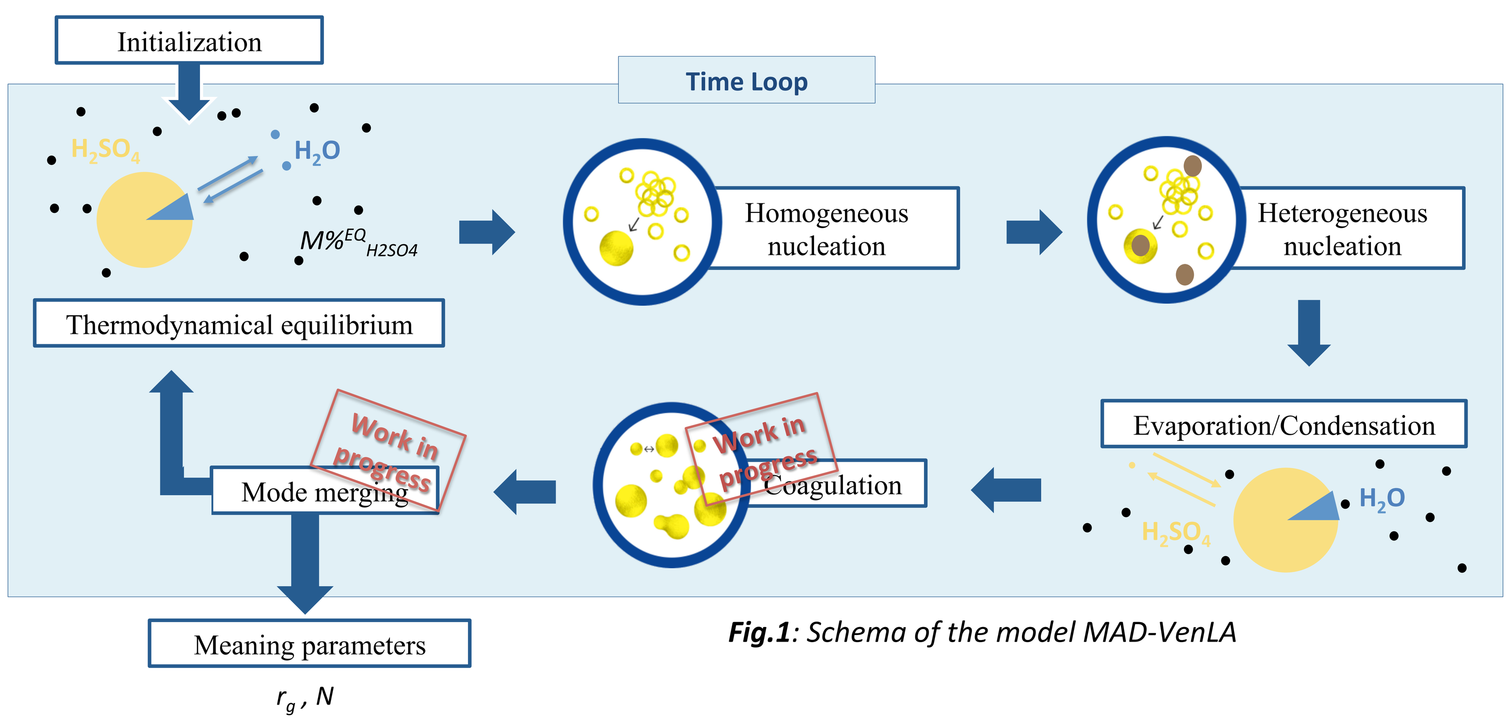


***Fig.1**: Schema of the model MAD-VenLA*

FIRST RESULTS of MAD-VenLA

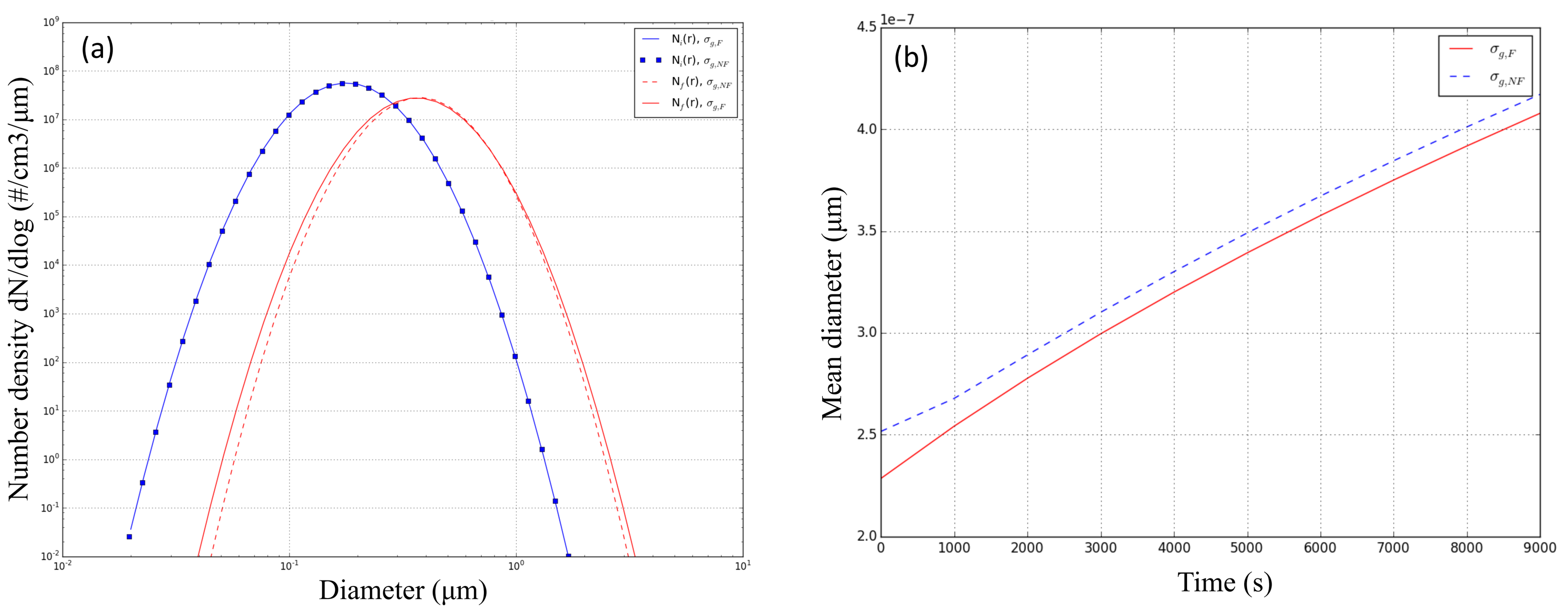


***Fig.2**: Study of the condensation with a standard deviation fixed and a case where the standard deviation isn't fixed. The number densities (a) and the evolution of the mean diameter (b) during the run (86400 s = 1h) are presented.*

STANDARD DEVIATION σ

- With the process of condensation, we compared two situations: with a fixed σ and with a variable σ (fig. 2).
- On 10 000 seconds of run, the total number of particles is conserved but the shape of the distribution vary.
- The difference between radii is 0.1 µm. With a fixed σ, we have an error of 4 % on the mean radius of the size distribution function.

CONDENSATION

- Two time steps are used here too dt_1=1 s and dt_2=15 mn or 86 400 s.
- The total number of particles is conserved for the final distributions in the two situations and between the initial and the final distribution in each case.
- The mean radius with 15 mn time-step is 0.15 % bigger than the mean radius with 1 s time step.

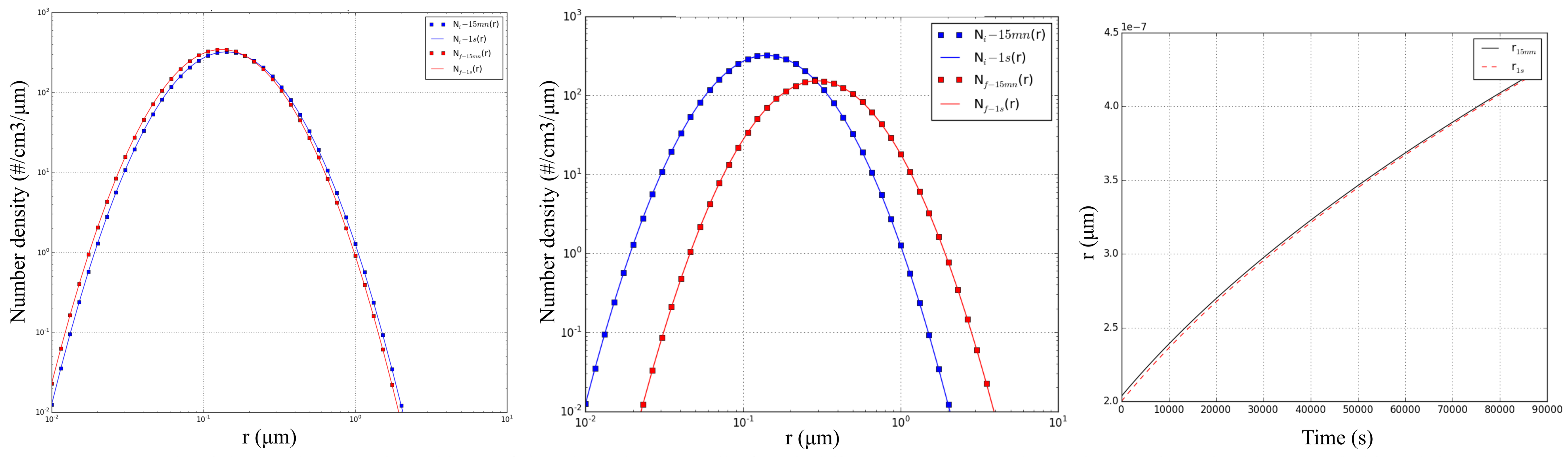


***Fig.3**: Study of thermodynamical equilibrium (a) and condensation (b,c) with different time steps. The evolution of number densities (a,b) and the mean radius (c) of the size distribution functions are presented. The time step of 15 minutes is the value of the chemistry time step in the IPSL Venus-GCM.*

THERMODYNAMICAL EQUILIBRIUM

- Two time steps are used here dt_1=1 s and dt_2=15 mn or 86 400 seconds.
- The total number of particles is conserved.
- The weight fraction of sulphuric acid in droplets, at the end of the run, is the same in the two cases.

MAD-VenLA vs VenLA

- With the same initial conditions, we obtain the same results between VenLA and MAD-VenLA for the condensation (a) and the nucleation (b, c).

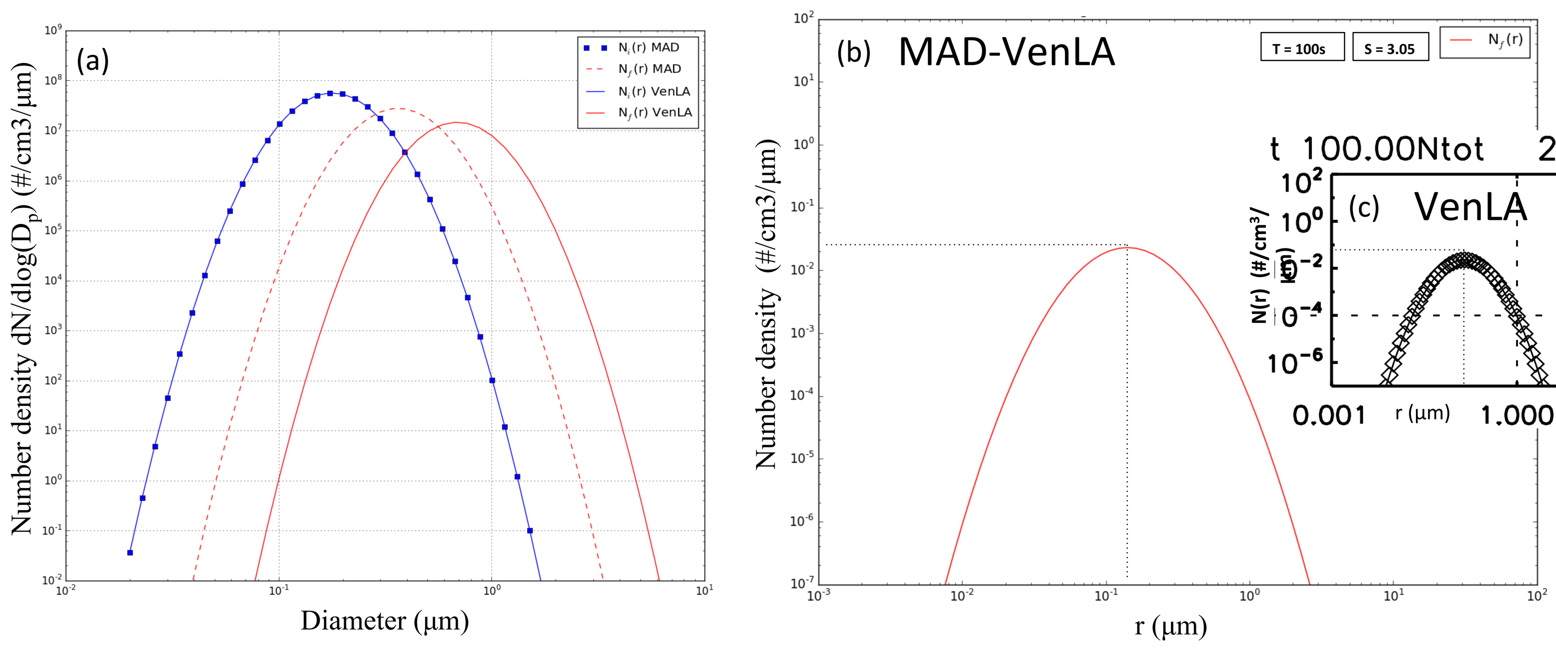


***Fig.4**: Comparison between MAD-VenLA (a,b) and VenLA (a,c). We obtain the same results with the same initial conditions. The figure (a) present the condensation with MAD-VenLA and VenLA. The figure (b) is a result of homogeneous nucleation with MAD-VenLA and the last figure (c) is the results of VenLA with homogeneous nucleation.*

CONCLUSION

- Here, we present a status report of MAD-VenLA. The results of the thermodynamical equilibrium and the homogeneous nucleation are **similar between VenLA and MAD-VenLA**.
- For the condensational process, with the same initial state and particle distribution, we can see a difference between MAD-VenLA and VenLA. In fact, the sectional model condense more than the modal representation. The validation of MAD-VenLA will be done with all processes and a comparison with baseline high-resolution models in literature [2].

PERSPECTIVES

The question is: what is the best representation to choose for coupling microphysics with the IPSL 3D Venus GCM? This will be evaluated based on tests on the tradeoff between precision of calculations and computational efficiency.

The finished version of MAD-VenLA will be integrated in the Global Climate Model and will be coupled with the chemistry to obtain first result of the complete IPSL Venus-GCM.

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